PROGRESS REPORT ON BERTELSEN RESEARCH AND DEVELOPMENT OF AN AIR CUSHION CRAWLER ALL-TERRAIN VEHICLE †

by W.R. Bertelsen, FCASI

Bertelsen, Inc. U.S.A.

SUMMARY

The ACV is an exceptional amphibian but it is not, nor is any other existing craft, an All-Terrain Vehicle. Using the best elements of the ACV in an Air Cushion Crawler Tractor, a true ATV can be attained.

A conventional crawler drive train will propel two tracks as pressurized, propulsive pontoons. The key to a successful ATV is in perfecting efficient, durable, sliding seals to allow the belt to move in its orbit around the track unit and maintain its internal pressure.

After deriving the adequate seal, a 12 inch wide × 86 inch long endless rubber belt was fitted with bilateral seals and slide plates with internal guide wheels fore and aft with a 21 inch wheel base.

From this approximately one-quarter scale model, full scale Air Track Crawlers, true ATVs, of any size and capacity can be produced.

INTRODUCTION

The Air Cushion Vehicle (ACV) is an exceptional amphibian capable of high speed over water and level surfaces. It carries massive loads over this type of terrain, but it is not, nor is any other existing craft, an all-terrain vehicle. Both the ACV and the ATV have serious shortcomings and cannot travel over difficult terrain nor operate in adverse conditions.

The purpose of this paper is to describe progress made by Bertelsen Inc. on research and development of an air-cushion crawler all-terrain vehicle.

AIR CUSHION CRAWLER ALL-TERRAIN VEHICLE

The key to a practical Air Cushion Crawler is its sliding seal, the interface between the orbiting and non-orbiting or stationary parts. This element both seals in the pressure and allows oscillating, orbiting motion of the crawler track. The bag seal, which is not unlike a simple bag skirt of the most elemental ACV skirt type, was arrived at after considering many other types of seals (References 1 and 2).

To test the effectiveness and efficiency of the bag seal, a circular 20-inch diameter plywood mockup of the rubber seal was built. (See Figure 1.) It was designed to be mounted on the head stock of a lathe for testing the seal gap at zero and high speeds to record cushion pressure and air flow quantities. The drawing (Figure 2) shows the rubber bag seal mounted on the plywood base, which in turn is mounted on the face of the lathe. On the tail stock centre point is mounted a circular, laminated, plywood structure which does not rotate. It supplies air pressure to the system from a shop air line through a Dwyer air flow gauge. A pick-up line to a Dwyer one-to-ten psi dial type pressure gauge records cushion pressure. The surface of this structure is covered with 1/4-inch polyethylene sheet plastic to provide a smooth surface for the rubber seal to pass over.

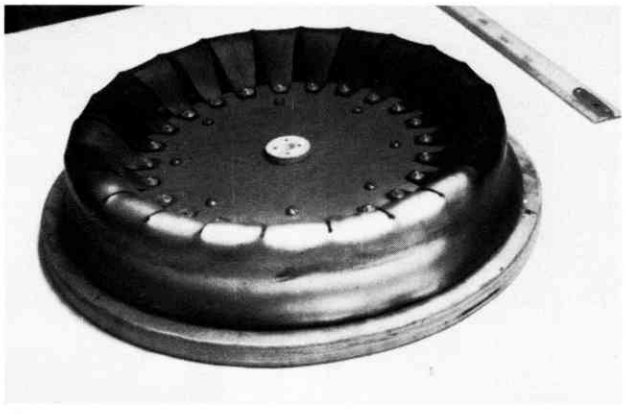


Figure 1
20-inch diameter bag seal mounted on plywood backing

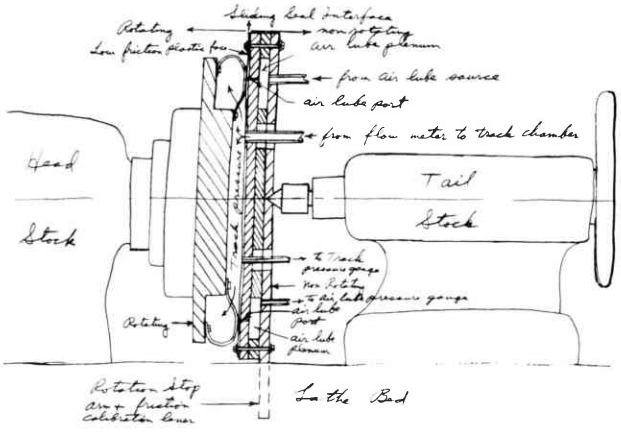


Figure 2
Sketch of lathe-mounted 20-inch diameter bag seal model with slide face, air pressure supply, and pressure pickup

† Paper presented to the Canadian International Conference on Air Cushion Technology, September 16, 1986, Toronto, Ont.

In the expectation of the need for air lubrication to the bag seal point of contact with the slide face, a circular plywood backboard with a chamber (labelled: 'air lube plenum', Figure 2) with an air inlet port was built. However, this was never used because the escaping cushion air between the rubber bag and the plastic face provided exactly the right air lubrication. The photo in Figure 3 shows the assembly mounted on the lathe with the slide face unit pressed against the bag seal deflated, air off. The photo in Figure 4 shows the unit inflated through the stationary central track pressure line. The Dwyer air flow gauge records 10 c.f.m. (see arrow) and the Dwyer pressure gauge records just under one psi. With greater closure of the head stock and a further reduction in the bag seal gap, the air flow was reduced to 2 c.f.m. In this condition, the rotating bag seal on the left could be freely turned on the head stock by hand and would run with lathe power at high speed (245 rpm) without significant drop of pressure or increase in air flow. Even though the bag seal was imperfect in structure (witness the cemented and riveted joints in Figure 3), there was only minimal air flow escaping from the interface at full pressure of one psi. The air flow was undetectable by 'feel' and was insufficient to blow out a match held close to the gap (except at the joints). The seal periphery was 4.65-feet long, which calculates to 0.33 c.f.m. per foot of seal length at one psi. This number is higher only because there was leakage at the two rubber seal joints. There was no evidence of wear on the polyethylene slide face or seal.

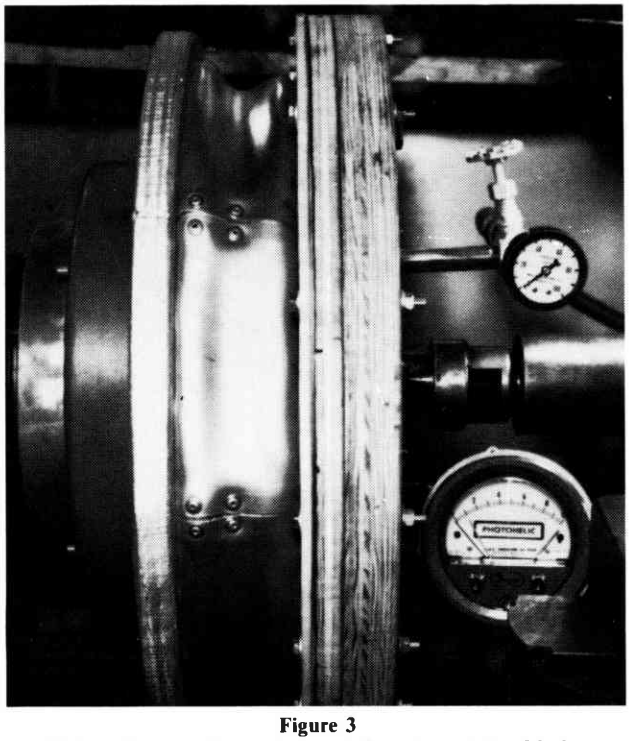


Figure 3
20-inch diameter bag seal mounted on face plate of lathe, faced up to the slide plate, deflated, air off

The requirements for a simple, inexpensive seal having been satisfied, the design of an Air Track model was undertaken.

The size of the model was dictated by a 12-inch wide by 86-inch long, closed end, 1/4-inch thick rubber belt kept on hand since the 1960 Air Track model (Figure 15), the first Air Track hardware to be constructed. The new model has 14-inch O.D. pneumatic wheels on 21.3-inch centres to guide the belt from inside (Figure 7).

The next problem was to design the bag seal for the model smaller than the 1/4-inch diameter of the track. This would allow 'squash' and oscillation of the top and bottom runs of the track under various terrain and pressure conditions. Thus, the slide plate would not drag on the ground and the unloaded top run of the track could have excursion room above.

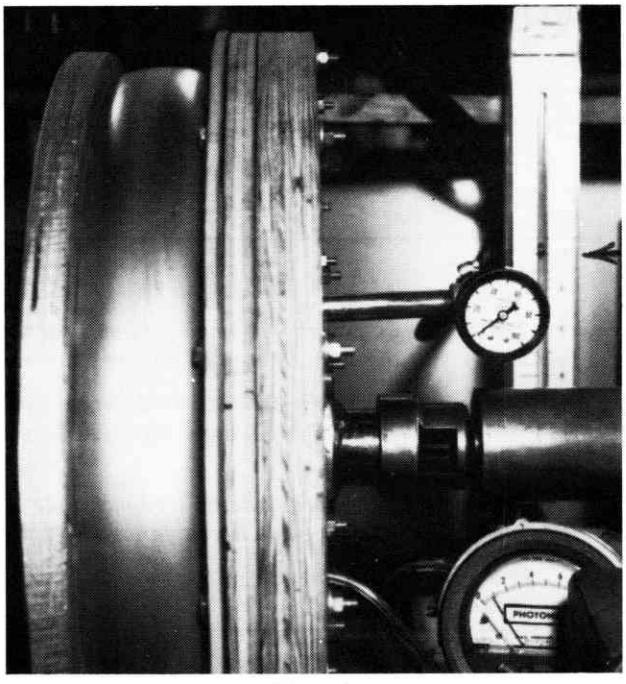


Figure 4
Bag seal as seen in Figure 3 with air flow of 10 c.f.m. at about 1 psi and frictionless in rotation

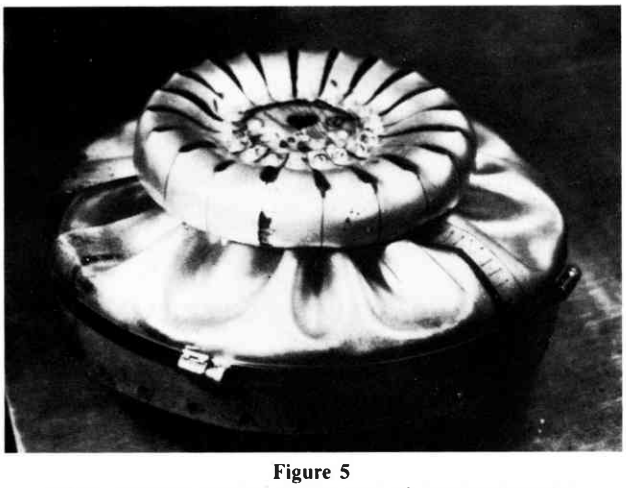


Figure 5
9-inch diameter mockup sliding seal of Air Track model with 14-inch secondary air bag

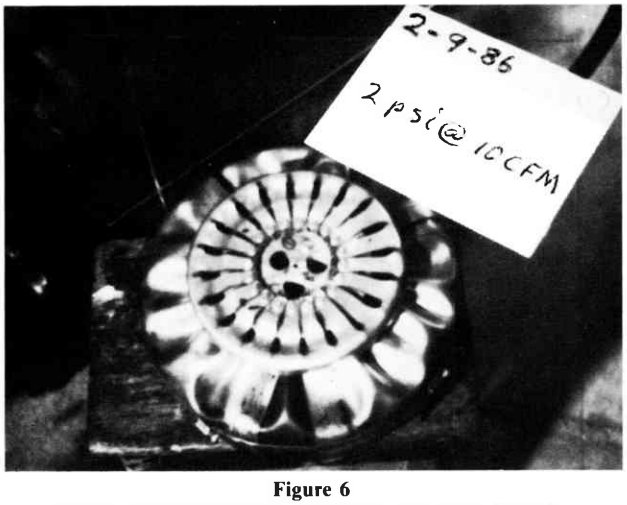


Figure 6
9-inch diameter mockup of sliding seal of the 14-inch Air Track model with plate glass as side plate

A 9-inch O.D. bag seal was selected with a secondary bag between the smaller 9-inch seal and the larger 14-inch belt guide wheel diameters. It took considerable cutting and fitting to arrive at the notch width and centre-anchor diameter for the tension-stressed bag seal to allow a smooth face under pressure without wrinkles or gaps. The final 9-inch O.D. circular bag seal with its secondary 14-inch O.D. bag is shown in Figure 5. The photo of Figure 6 (February 9, 1986) shows a near-verticle view of the dual bag on a stationary mount with an invisible plate-glass slide face pressed down on it, air pressure off. A pressure of 2 psi at 10 c.f.m. was obtained by pressing down hard on the plate glass. The 9-inch diameter circular seal has a 2.356-foot circumference and, at 10 c.f.m., required 4.244 c.f.m. per foot of periphery *at 2 psi, about 12 times the airflow for 1 psi* in the 20-inch diameter, lathe-mounted model. However, the plate glass could not be held parallel to the plate glass seal by hand and on the model. Thus, the 10 c.f.m. airflow was probably far greater than it would be in a structured system.

One can extrapolate the air-flow volume for the ATC model under ideal construction and function conditions. The 9-inch bag seal at 21.3-inch centre spacing will have a length of 70.87 inches (5.9 feet) and there will be one on each side, or 11.81 feet of seal length. The air flow required (ideally) should be 0.33 c.f.m./foot times 11.81 feet (to equal 3.90 c.f.m.) to maintain one psi cushion pressure. One can expect that considerable improvements in efficiency can be made through adjustment, better bag seal patterns, etc.

In contrast, the open skirt ACV at 0.25 psi requires hundreds or thousands of c.f.m. depending on its size and, even at this low pressure, stirs immense spray and dust with resulting surface erosion. The Air Track will produce minimal efflux at four times the cushion pressure and will enable a reduction in overall size of the craft to one-quarter of the base area at the same gross weight, quite a considerable economy and a very significant design advance.

The value of pursuing this line of research becomes apparent when these advantages are added to the fact that the Air Track has, inherently, very efficient propulsion like a tractor or truck, has excellent control or steering like a crawler tractor or tandem dual-unit tractor, has 45° grade-climbing capacity, and will, with crawler treads as tough as tire casings, step over high obstacles and travel over very rough terrain, stumps, stakes, and heavy brush without damage.

The 'propulsion pontoon' Air Track unit provides inherent flotation to the ACV. When designed so that the craft floats on water at full gross weight with the Air Track only half or less immersed, the bottom run of the tread with segments or 'grousers' will provide an enormous paddle wheel effect to provide excellent traction on water or other surfaces.

The details of the model are shown in the Figures 7, 8, and 9 where the 12-inch wide belt is spanned across the top surface by 52 one-inch × one-inch × 1/8-inch thick steel angle iron 'grousers' to stiffen it laterally and provide traction. Bolted inside the belt to each angle on each side are the bag seal straps pointing radially inward normal to the belt and offset 2 inches laterally. The pneumatic wheels can be seen through the straps (Figure 7). There is a wooden spacer bar to maintain belt tension. The bag seal and the secondary bag are bolted to the tips of these radial straps as shown in Figure 8. The bag seal is lax and wrinkled because it is unpressurized and is supported in position with wire hooks for photographing. Figure 9 shows the slide plate axle bearings pressed against the unpressurized bag seal. Figure 10 shows the Air Track model inflated to 0.7 psi, as shown on the Dwyer gauge.

Early tests of the completed pressurized Air Track model show an air flow demand of 30 c.f.m. at 0.7 psi. With careful adjustment, this should be much improved.

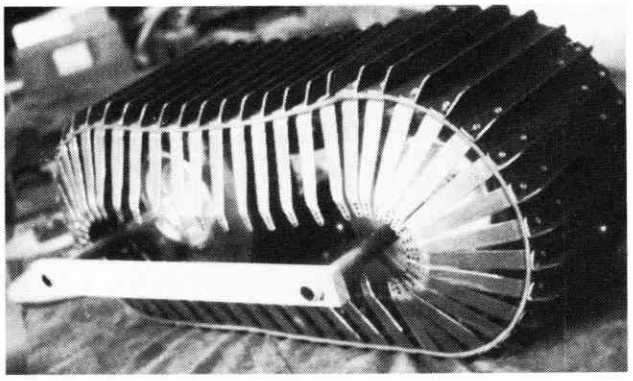


Figure 7
Air Track model showing the radial bag seal mount straps and the pneumatic guide wheels

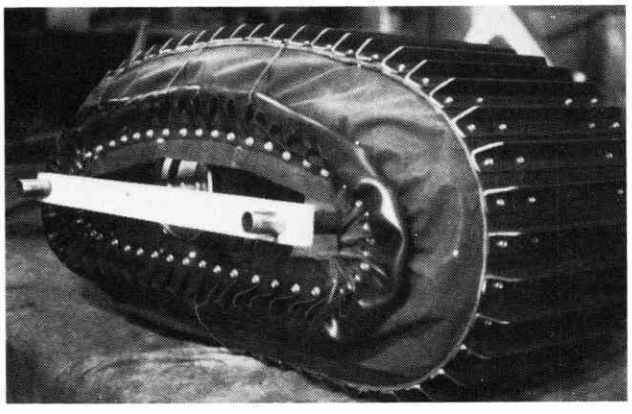


Figure 8
Air Track model with the 9-inch orbital bag seal and 14-inch secondary bag mounted

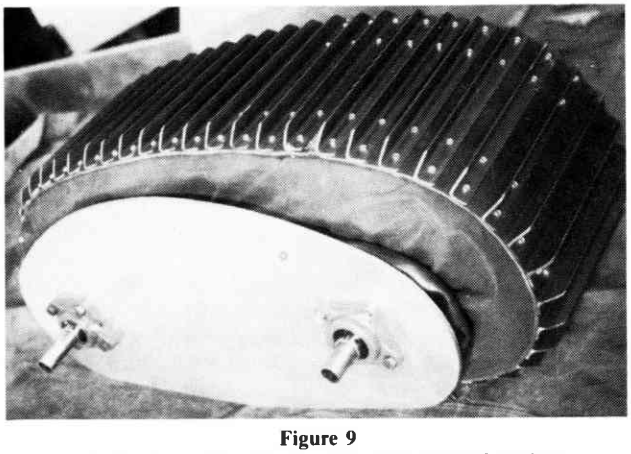


Figure 9
Air Track model with the slide plate pressed against the unpressurized orbiting seal bag

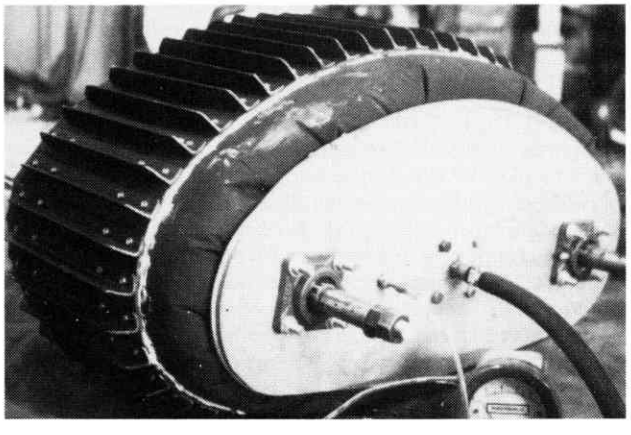


Figure 10 ——→
The Air Track model inflated to 0.7 psi

When the Gordian knot of the sliding seal is finally solved, the way is open to create far more capable, efficient, and useful craft — true ATV's which do not get stuck in mud, sand, or snow and will travel at good speed on water.

Several examples from Reference 2 are shown here in the following illustrations: Figure 11, a tandem, dual-track amphibian capable of carrying 7 tons at one psi base pressure while floating only 27-inches deep.

The capacities and flotation depths of Articulated, Tandem, and Dual-Segmented Air Track Vehicle (two 7-foot × 7-foot) crawler tracks with a total bearing area of 98 square-feet are as follows:

PSI	Carrying Capacity	Flotation Depth
1	14,112 lbs. (7 tons)	27 inches
2	28,224 lbs (14.1 tons)	54 inches
3	42,336 lbs. (21.2 tons)	71 inches
10	141,120 lbs. (70.6 tons)	—

Specifications of 'Model T' Four-Passenger Segmented Air Track All-Terrain Vehicle:
Gross weight , 3,000 lbs.; *Empty weight*, 2,000 lbs.; *Payload*, 1,000 lbs.; *Flotation*, (fully amphibious): in tracks at 50% immersion, 4,800 lbs.; in Hull, 3,000 lbs. *Track dimensions*: overall length, 90''; overall height, 42''; width, 18''. *Power*: 50 HP gasoline engine. *Speed*: on land, 20+mph; on water, 10+mph. *Grade climbing*: 45 degrees. *Obstacle clearance*: 16''. *Tread pressure* on ground at 3,000 lbs. gross wt.: 1.4 psi (area of tread contact 60'' × 18'' × 2 tracks = 2,160 sq. in.

A 'model T', four-passenger, truly 'All-Terrain' craft is a very real possibility. Such a rugged utility craft, unlike its nearest rivals, the Cushman Trackster, the four-, six-, and eight-wheel Rollegon vehicles, would be buoyant with full propulsion, steering, and land speed. Water speed of two mph is the usual velocity for these extant craft. The Air Track can achieve 'hump speed' and climb out of its static, buoyancy immersion depth to travel on the surface above five-to-ten mph, depending on the length of the craft. The descending leading edge of the Air Track will climb on the inertia of the bow water; its delay in moving away from the rapidly downwardly cascading cleated belt will force the nose of the craft upward. As the process of impelling cleat after cleat faster than the water can yield continues, the entire craft will be lifted to and maintained on the surface as long as the track velocity is sustained. The improved efficiency and increased top speed propulsive horsepower, if 'hump speed' is achieved, is obvious. A corroborating analogy to this 'hump speed' theory is the observed phenomenon of the non-buoyant snowmobile and its ability to skitter across a narrow open-water area at high speed without observable sinking. All too many snowmobiles, however, have tragic outcomes on thin ice.

The propsed ATC has 100% gross weight buoyancy in each of its two widely-spaced tracks which are designed to be only 50% or less immersed in full, gross-weight operation. The wide stance, nearly eight-foot beam, plus the great buoyancy of each track unit, should render the craft quite stable and capsize-resistant in sliding off sideways, for instance, from an ice shelf, or a sheer-drop shore edge with the water level near or below the solid surface.

In 1977, David Eyre[3], Senior Research Scientist of the Saskatchewan Research Council, made a plea to air cushion designers to provide life during the spring banned period when heavy loads are forbidden on the public roads because of their weakened state during the spring. To quote Reference 3, ". . . . there is one compelling argument in favor of such development (air cushion assist for prairies' weak-road load relief) — *the number of potential users is one or two orders of magnitude greater than the total number of potential users of all other ACV vehicle types.*" In other words, the market for such a device is huge, *probably the largest of all ACV markets.*

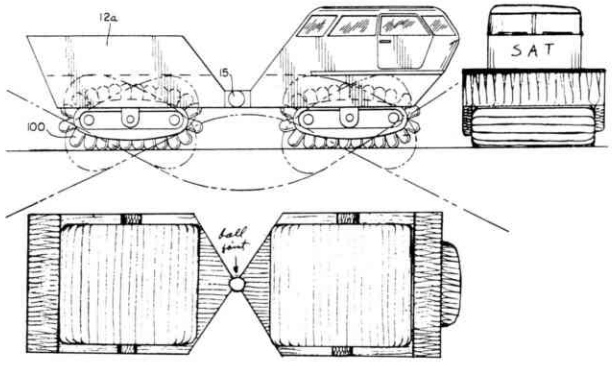


Figure 11
Tandem dual amphibian Air Track vehicle with nearly the total base covered by crawler tread for very light ground pressure and massive load carrying

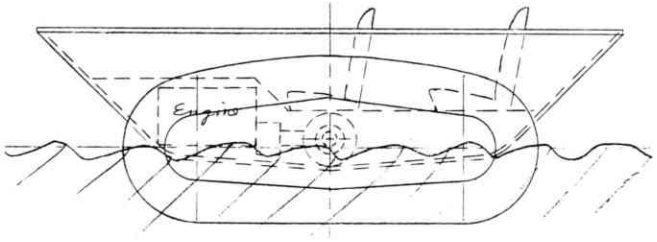


Figure 12
The 'Model T' amphibian, dual-track, four-passenger, Air Track of 3,000 lbs. gross weight at 50% track immersion and 1 psi (Reference 2)

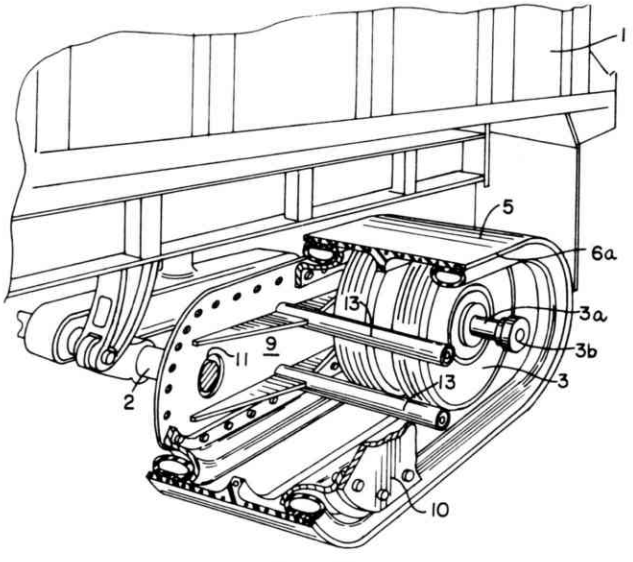


Figure 13
From U.S. Patent No. 4,283,094; Canadian Patent No. 380,371

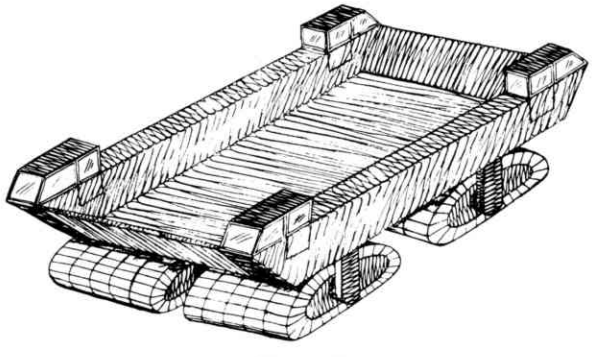


Figure 14
50-ton payload amphibian Air Track All-Terrain Vehicle

In the 1970's, the National Research Council of Canada did extensive studies on air cushion lift assist of semi-trailers and other techniques for load relief (Reference 4). None was considered feasible with 'conventional' ACV or extra wheels, Rollegons, etc. Four billion tons of commodities, ore overlay, and other cargo cross Canadian prairies annually, most of it in semi-tractor trailers, and it slows drastically during the three months of each year as the Spring break-up occurs. This movement should occur and is, therefore, a severe, continuing, unresolved economic deprivation.

In 1979 the author made a presentation (Reference 1, Figure 13) which proposed the conversion of semi-tractor trailer, tandem dual-wheel sets to enclose them in a belt with peripheral seals, side pressure plates, and an external air pressure supply to pressurize the unit to increase the ground contact area from three square feet to 30 square feet per tandem pressure to ten psi or less, instead of 75-100 psi in the truck tires.

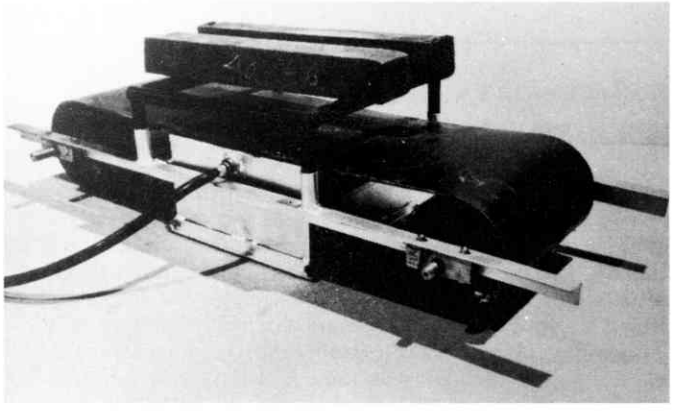


Figure 15
First Air Track model of 1960

Figure 13 shows an earlier patent drawing (References 5 and 6) of a bolt-on Air Track for a semi-tractor and trailer, tandem dual-wheel set. The sliding seal on this concept was different from the current bag seal design but the orbiting heavy duty traction belt with its central rib, circumferentially-imbedded tension cables, side plates, wheel bearings, tension member cross bars, axle entry ports are the same as if converted for the bag seal concept. The new bag seals would be belt-mounted rather than side-plate mounted, as in the configuration of Figure 13 (see also References 7 and 8).

It is quite feasible to bolt-on to the tractor or trailer tandem dual wheels, attach slide plates, put on the belt and slide seals, and install an air pump to retrofit existing semis. This conversion may well solve the prairies' weak-road, load relief problem. It would also allow off-road operation of these rigs, and overloading for on-road operation the rest of the year without road damage. It could save millions of dollars in road construction and repair. To reiterate, this could be the largest of all ACV product markets and could finally solve forever the costly, persistent, unresolved annual weak-road, spring breakup havoc in Canada.

To illustrate the possibilities for the growth of the ATC craft and to offer the offshore oil drillers in the Beaufort Sea an efficient tug for pushing or pulling and supplying their 300-ton ACV oil rig transporter on land and sea the year round, the author has proposed[2] a 50-ton payload, 100-ton gross weight vehicle shown in Figure 14; specifications are listed in Table I showing four 15-foot square area ATC units on each corner of the craft, each one of which would support 50% of the gross weight when fully immersed, and any two of which would support 100% of the gross weight fully immersed, making the craft more stable on water than barges or conventional ACV's. The total movement of the immersed buoyant parts would provide tremendous paddle wheel propulsion and drawbar pull. On land, the traction would be even greater. This too, huge as it is, is a true All-Terrain Vehicle. And this is not the maximum size nor load-carrying capacity of the ATC concept. Theoretically, millions of pounds of ATC capacity can be built for amphibious operation.

Table 1
50-ton Air Track tug specifications

Overall Dimensions: Height on solid surface on cushion, 21 ft.; *Height* on solid surface off cushion, kneeling, to well deck, 8 ft., overall, 17 ft.; *Width*, 38 ft.; *Length*, 56 ft.; *Well Deck and Cargo Bay* dimensions: Depth, 6 ft., Width, 32 ft., Length, 45 ft.; *Gross weight,* 210,600 lbs. (105.3 tons). *Flotation*, Fixed permanent in structure, 220,000 lbs. (110 tons and 4.7 tons greater than gross weight); *Maximum Air Track Buoyancy* at 100% immersion, 421,200 lbs. (210.6 tons or twice the vehicle gross weight). *Normal Air Track Buoyancy* at 50% of track height immersion, 210,600 lbs. (105.3 tons, equal to craft gross weight). *Maximum Payload* of full gross weight, 114,600 lbs. (57.3 tons). *Power:* Four 1,000 HP Diesel engines. *Tread Pressure* on ground: 2 psi. *Speed*: on water, two to 20 knots; on land, maximum 30 knots. *Grade climbing:* 45 degrees or whatever slopes traction will allow. *Drawbar Pull* (estimated): On water, 80,000 lbs. On land, 160,000 lbs. *Maximum Obstacle Clearance,* 8 ft. (Reference 2)

CONCLUSION

The Air Track is a new application of air cushion technology. It can extend and in increase many fold the capability and utility of the ACV.

REFERENCES

(1) **Bertelsen, W.R.** — *Proposals for Comprehensive Overland Heavy Transportation for All-Season, All-Climate via Air Cushion Systems*, **Proceedings of the Thirteenth Canadian Symposium on Air Cushion Technology, September 17, 1979.**

(2) **Bertelsen, W.R.** — *The Segmented Air Track Amphibious All-Purpose All-Terrain Vehicle,* **Proceedings of the Seventeenth Canadian Symposium on Air Cushion Technology, October 4-6, 1983.**

(3) **Eyre, D., Saskatchewan Research Council** — *On-Road Air Cushion Assist: Where Is It When We Need It?,* **Tenth Symposium on Air Cushion Technology, CASI, Calgary, Alberta, October 25-27, 1976.**

(4) **Fowler, H.S. and Harcourt, C.** — *Prairie Weak Road Relief Program,* **Eleventh Canadian Symposium on Air Cushion Technology Section of CASI, Vancouver, B.C., September 19-21, 1977.**

(5) **U.S. Patent No. 4,283,094, Air Suspension System for Vehicle Track.**

(6) **Canadian Patent No. 380,781, Vehicle Suspension System.**

(7) **U.S. Patent No. 4,530,545, Segmented Air Track Apparatus.**

(8) **Canadian Patent Application in process: Segmented Air Track Apparatus.**